the country are affected by North-West winds, while the south – by the South and North winds.

2. The assessment of the long-term variability of wind speed indices (1957-2010) helped to identify high values (3.5-4.5 m/s) during the winter and spring seasons with the maximum in the February and March. The lowest values (2.3-2.0 m/s) are characteristic to August and September.

3. Certain changes in the wind regime, specifically a decreasing tendency of wind speed have been revealed over the whole territory of the Republic of Moldova during the second half of the 20^{th} century. This pattern is characteristic to the first decade of 21^{st} century.

Reliable knowledge on current pattern of wind mode is important specifically to those involved in agriculture and environment protection sectors. The indicated researches may be also particularly interested in promoting and developing the renewable energy sources in the Republic of Moldova.

Bibliography

1. Lasse G.F. *Climate of Moldavian SSR*. Leningrad, Gidrometeoizdat, 1978, 374 p.

2. Baranova A.A., et al. *Izmenenie gradyirovanich skorostei vetra v Rossii vo II-oi polovine XX veka*. Tr. GGO, 2007, vipusk 556, p. 116-139.

3. Pryor S. et al. *Wind speed trends over the contiguous USA*. 2009, J. Geophysical Research, N114, p. 183-198.

4. Troccoli A., et al. *Long-term wind speed trends over Australia*. J. Climate Research, 2012, N25, p. 170-183

5. Vespremeanu – Stroc A., et al. *The wind regime of Romania – characteristics and North Atlantic Oscillations influences*. Forum geografic. Studii şi cercetări de geografie şi protecţia mediului Volume XI, Issue 2 December 2012, p. 118-126

*http://dx.doi.org/10.5775/fg.2067-*4635.2012.003.d

6. William J. Baule. *A climatological analysis of the warm-season wind regimes of the Beaufort / Chukchi seas coasts*. A thesis for the Degree of Master of Science. University of Nebraska, 2012, 83 p.

SIMULATION OF THE FLOOD DYNAMICS IN THE BALTATA RIVER USING THE JAMS/J2000 HYDROLOGICAL MODEL

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Abstract. The paper represents the first attempt to apply hydrological modeling for simulation of flood dynamics on rivers of the Republic of Moldova. Flood formation in the area is mainly caused by heavy rains which can reach more than 130 mm/d. This can cause serious floods with heavy casualties in lives and damages in infrastructure. The area chosen for this study is the Baltata River situated in the central part of Moldova. Simulation of the flood dynamics was performed using the physically-based fully-distributed JAMS/J2000 hydrological model which allows evaluation of natural and anthropogenic factors involved in the water balance and flood generation. The performance of the modeling is satisfactory considering that the anthropogenic influences like irrigation and reservoirs are not well known in the area and therefore only conceptually represented in the model. Additionally the existing data describing the situation in the basin are of low confidence. Specific flood formation processes were analyzed basing on 4 biggest flood events occurred in the Baltata River. Regionalization and representation of the geographical features has been conducted using the Hydrological Response Units (HRU) approach. This gives the possibility to analyze flood generation conditions in a fully distributive manner and allows to assess the influence of potential flood protection measures on the discharge. The changes in the past in the Baltata River basin are generally affecting the composition of land cover. The calibrated model was used to evaluate the impact of present/past and possible future land use changes on the discharge during floods. Also the influence of land use on floods in general has been analyzed to help to find solutions for a better water and land management.

Keywords: hydrological modeling, JAMS/J2000 model, floods, the Baltata River

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Introduction

In the Republic of Moldova flood generation is mainly caused by heavy rains which can reach more than 130 mm/d. Besides natural factors, anthropogenic activity can enhance flood magnitude through such processes as deforestation, urbanization, agriculture activities and reservoir operation. Assessment of human impact on flood generation is a challenging task which should lead to a better land management suitable for floods mitigation. This study represents the first attempt to apply hydrological modeling for studying flood dynamics under human influence on rivers of the Republic of Moldova. The study was performed on example of the Baltata River Basin. Following steps were conducted: (i) analysis of the time series and setup of the spatial database of the study area, (ii) hydrological modeling and analysis of the results, (iii) assessment of land use scenarios on the peak flow.

Methodology and database

Detailed monitoring on hydrological, meteorological, soils, groundwater parameters was performed during the period 1954-1994 at an experimental water balance station established in the basin. From 1997 till present the monitored parameters where reduced. For the present study the data on flow and climate for 1970-2009 were used [1, 9]. Gaps of discharge measurements are for the periods 1978-1983 and 1995-1997. The largest recorded pluvial flood events reach 1.62 m^3/s (5.06.1970), 4.18 (3.07.1975) (fig. 2), 1.27 m^3/s (9.06.1984), 2.96 m^3/s (5.06.2001), 3.66 m^3/s (19.08.2005) discharge. Daily precipitations which generate the flood events are between 35 (5.06.1970) and 141 mm (5.06.2001).

Spatial database consists of soil maps [4] and for land-cover – topographic maps (1:50.000 for 1982 and 2013) and Landsat images [7]. The land-cover was classified in 7 classes: settlements, grassland, forest, arable land, shrub (including vineyards, orchards), wetland and water. From the described spatial information model entities were delineated using Hydrological Response Units (HRU) approach.

Simulation of the hydrological dynamic was performed using the physically-based fully-distributed JAMS/J2000 hydrological model [5, 6] using daily time step. The model is designed for river basin modeling of rainfall-runoff processes and allows evaluation of the impact of natural and anthropogenic factors on the hydrological dynamic. The process simulation is carried out in independent simulation components (e.g. for snow, soil water and hydrogeological dynamics) that can be adapted, substituted or added depending on the models purpose and data availability. Most of the process components of JAMS/J2000 are characterized by conceptual algorithms that are widely used throughout the world. This model is able to represent the most important factors for flood generation and therefore is well suited as assessment tool for this study.

Study area

The catchment chosen for study is the Baltata River Basin (166 km^2). It is located in the central part of Moldova and is a tributary of the Dniester River. The morphology of the basin is hilly with altitudes between 18 m and 220 m (fig. 1). The area is characterized by a high proportion of degraded lands, 30.9% is eroded and 6.3% are occupied by landslides [3]. The lithology is dominated by clay, sands and limestones. These rocks are predominantly covered by typical black soils (cernozems) with an average depth of 70 cm and fluvisols in the floodplains. The texture classes of the soils are mainly loam clay (over 60%), loam (over 20 %) and sandy loam (10%). Typical groundwater depths range between 5m in the floodplain and 30 m on the top of the slopes. The climate can be characterized as semi humid, the annual average temperature is 9.5°C, annual average of precipitations is 530 mm with fluctuations from 349 (1982) to 696mm (1980). Average water flow of the Baltata River is 0.05m^3/s.

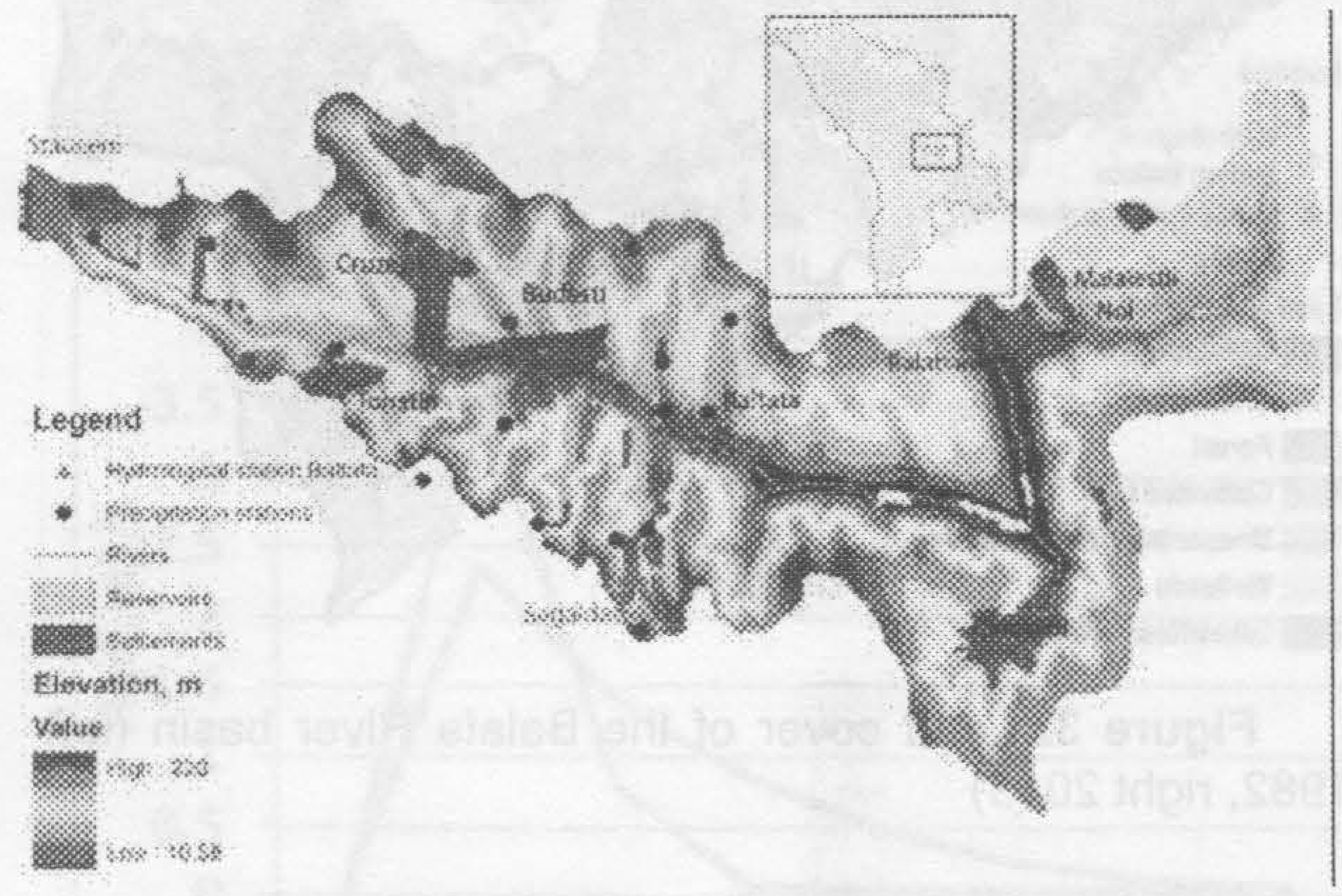


Figure 1. The Baltata River Basin

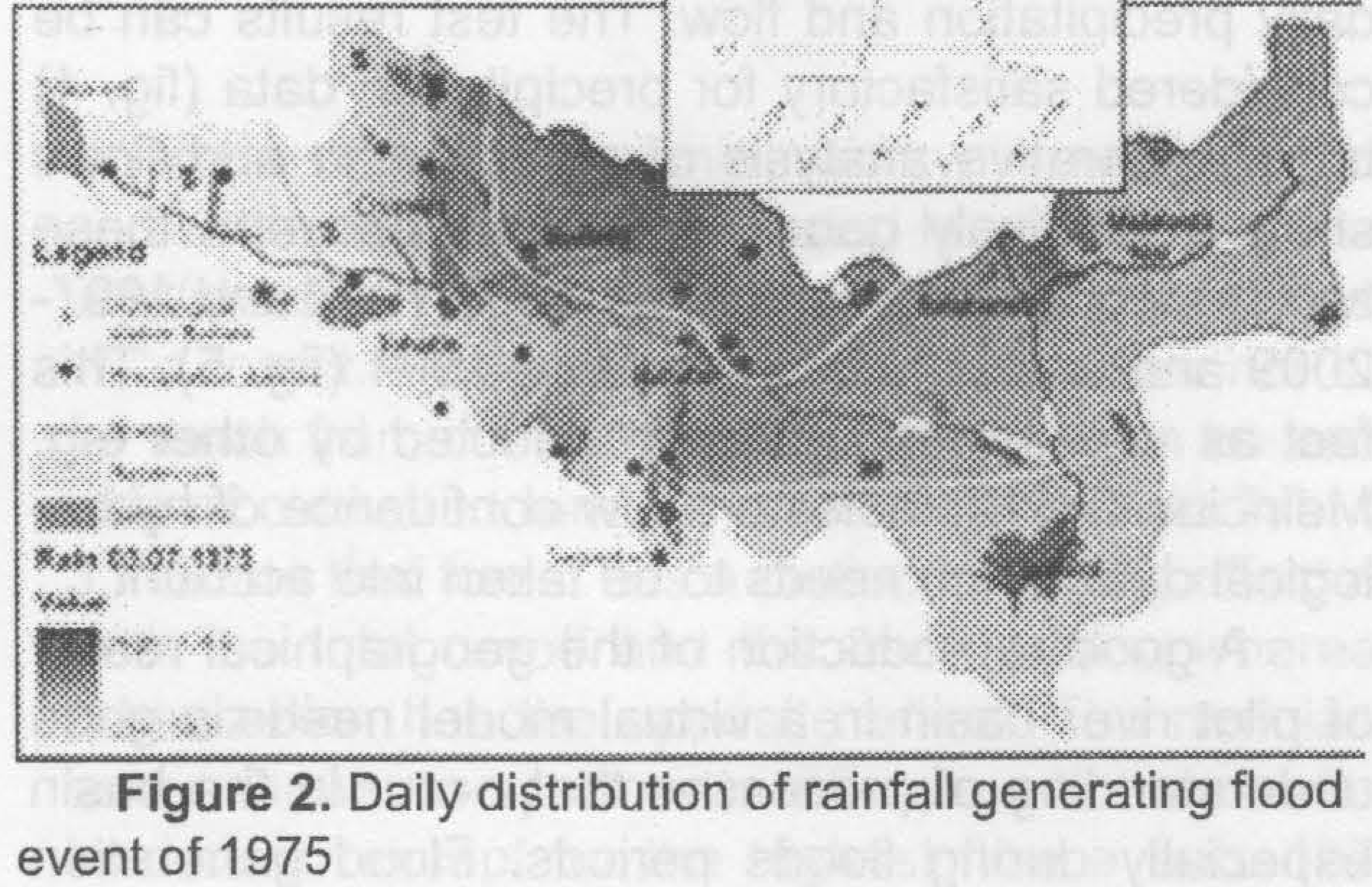


Figure 2. Daily distribution of rainfall generating flood event of 1975

The comparison of the land cover for the years 1982 and 2013 shows an increase of settlements and cultivated land area, forests and grassland and decreasing of areas covered by vineyards/orchards. The basin is dominated by agriculture with a proportion of over 50% of cultivated land; forests are only occupying 13-16% of the basin area (fig. 3). The situation regarding small reservoirs and ponds that were constructed in the river floodplain during the soviet period shows that they are out of use because of the accumulation of sediments.

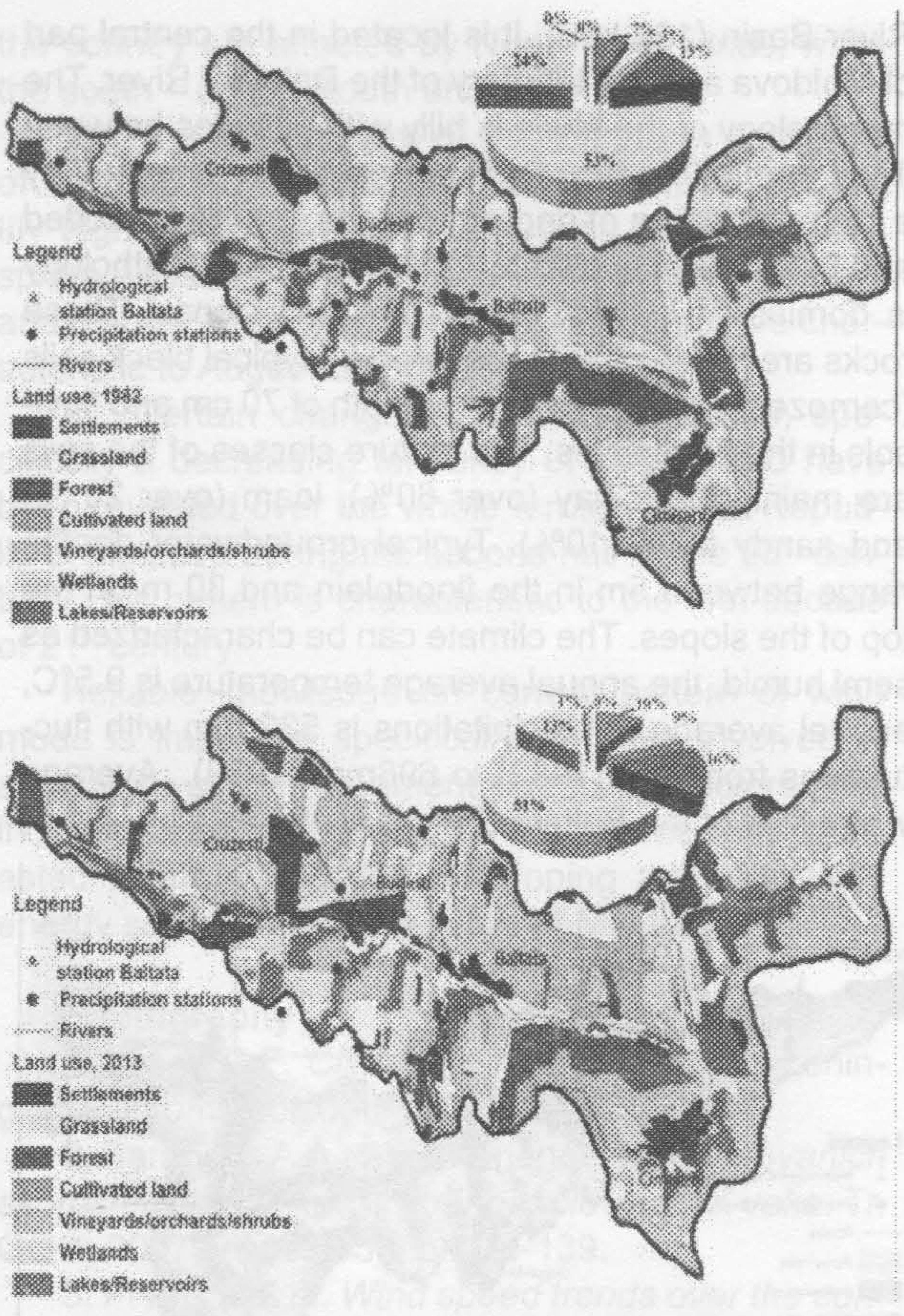


Figure 3. Land cover of the Balata River basin (left 1982, right 2013)

Results and discussions

Analysis of meteorological and hydrological data consistency was performed using double-mass analysis method and comparative analysis of log data for daily precipitation and flow. The test results can be considered satisfactory for precipitation data (fig. 4) but comparative analysis of precipitation and flows show a relatively good relationship between these two components for the period 1970-1977 and 1997-2009 and unsatisfactory for 1983-1994 (fig. 5). This fact as well as researches conducted by other e.g. Melnciuc O. [10] indicate a low confidence of hydrological data which needs to be taken into account.

A good reproduction of the geographical reality of pilot river basin in a virtual model needs a good understanding of processes that occur in the basin especially during floods periods. Flood generation processes are distinguished by non-stationary character. Important factors to be taken into account are of course flood generating factors: heavy rains and water retention factors: soil characteristics (especially actual soil moisture, infiltration and storage capacity, etc.), land cover (natural land cover and in particular anthropogenic changes: urbanization, plant cultivation), as well as hydrogeological parameters. All these factors were taken into account during the hydrological modeling process.

Model quality control was performed using four efficiency criteria: coefficient of determination (R2), Nash–Sutcliffe efficiency (E), logarithmic Nash–Sutcliffe efficiency (ln E) and percent bias of the total runoff (PBIAS) [8]. From the entire modeled period (1970-1978, 1983-1994, 1997-2009) four major flood events were identified and used to evaluate the dynamics (tab. 1, 2, fig. 6).

Table. 1. Simulation results and performance statistics for the Baltata flood events simulation

Event	Measured daily flow, m3/s	Maximal daily sum of precipitation, mm	Modeled daily flow, m3/s
04.06.1970-08.06.1970	1.62	35.3	1.5
02.07.1975-10.07.1975	4.18	96	2.2
07.06.1984-13.06.1984	1.27	63.9	1.7
12.08.2005-22.08.2005	3.66	67.4	2.3

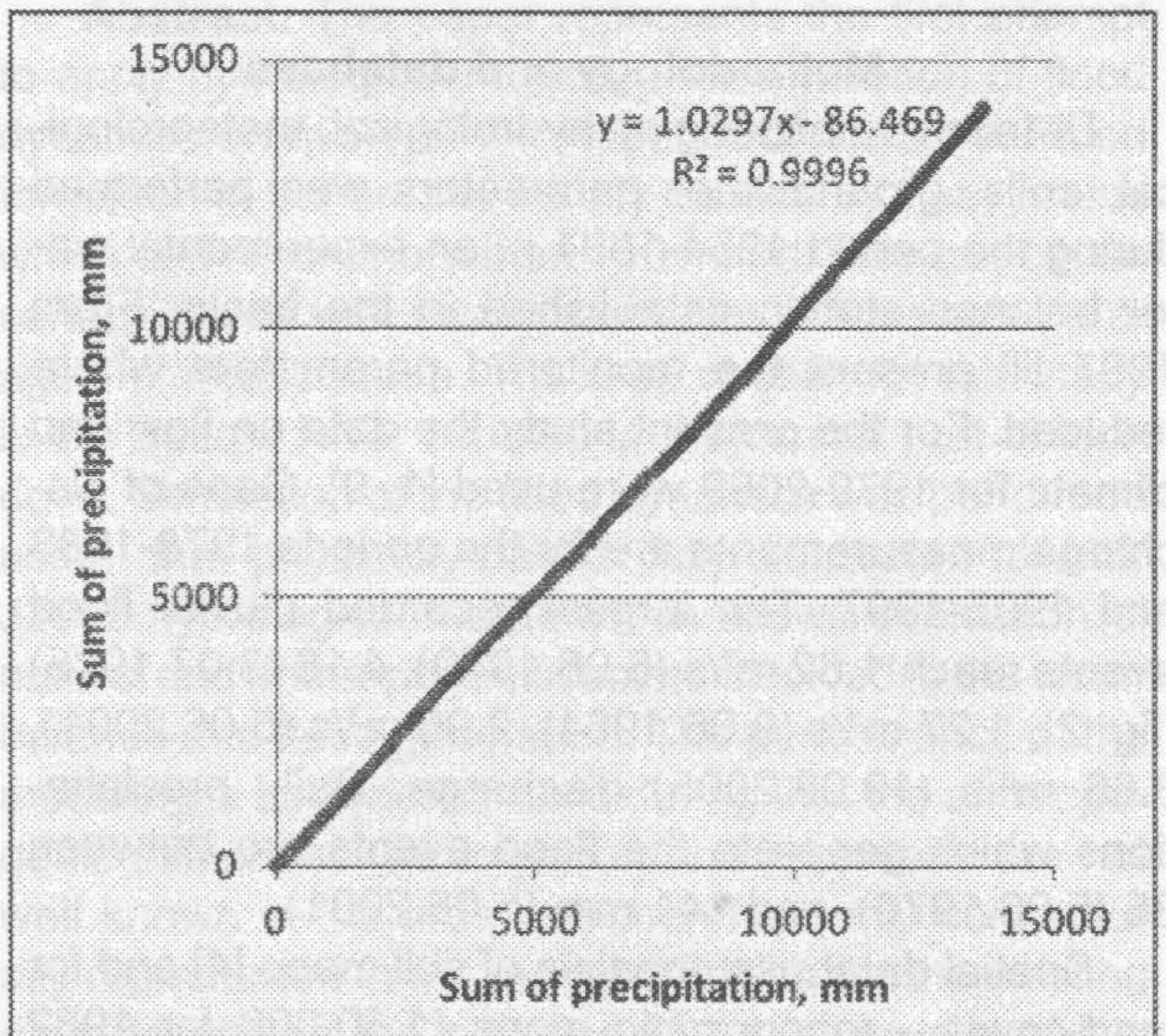


Figure 4. Double-mass analysis for daily precipitation (2 stations)

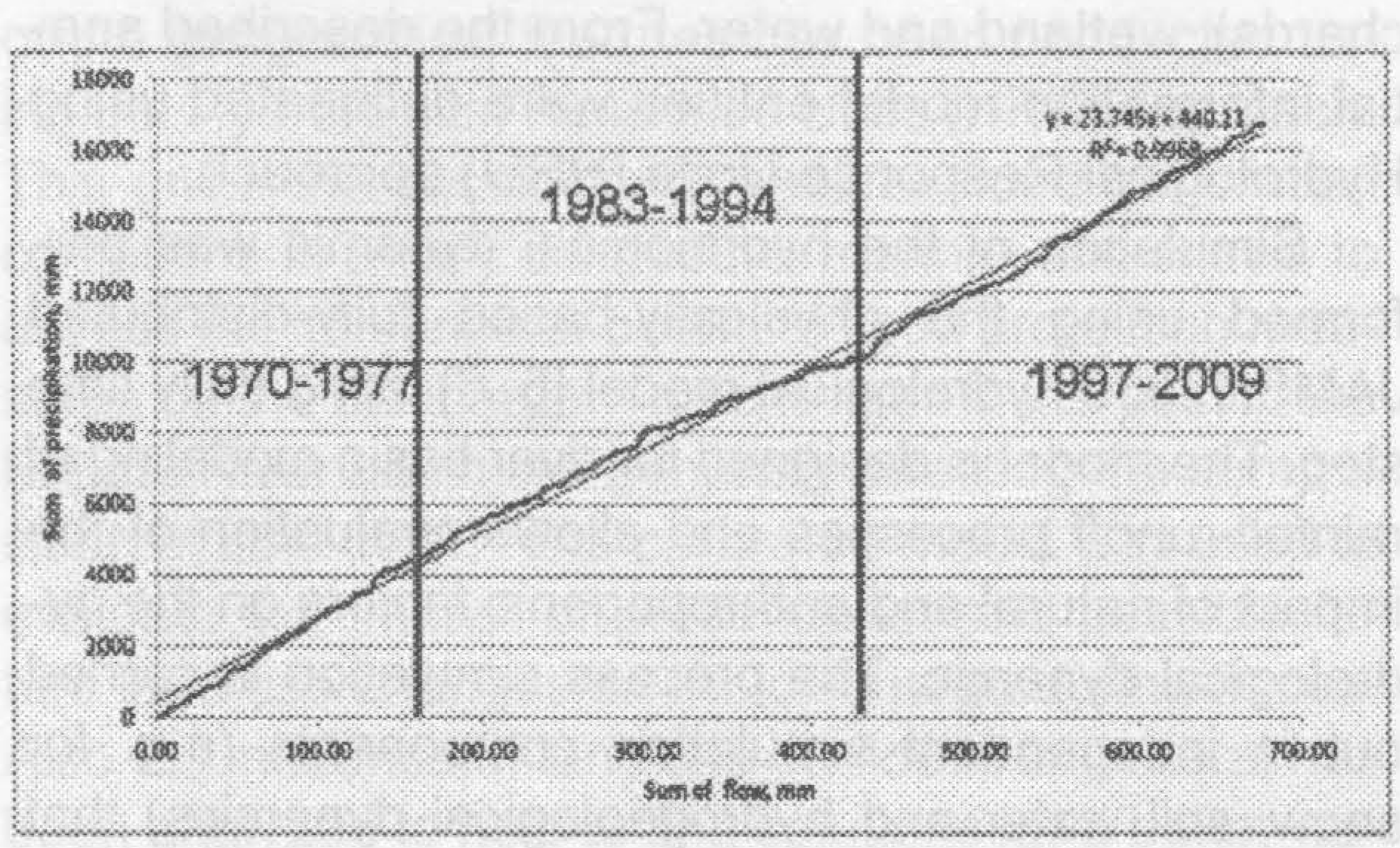


Figure 5. Double-mass analysis for daily precipitation and flow

The performance of the modeling is satisfactory considering that the anthropogenic influences like irrigation and reservoirs are not well known in the area and therefore only conceptually represented in the model. Additionally the data base itself can be classified as low confidence.

Table. 2. Performance statistics for the Baltata flood events simulation

Event	R2	E	Performance of dynamics	Ln E	PBIAS	Performance of volume
04.06.1970-08.06.1970	0.95	0.90	Very good	0.84	11.49	Good
02.07.1975-10.07.1975	0.89	0.71	Good	0.74	-21.41	Satisfactory
07.06.1984-13.06.1984	0.98	0.75	Good	-1.14	24.42	Satisfactory
12.08.2005-22.08.2005	0.79	0.76	Good	0.67	10.58	Good

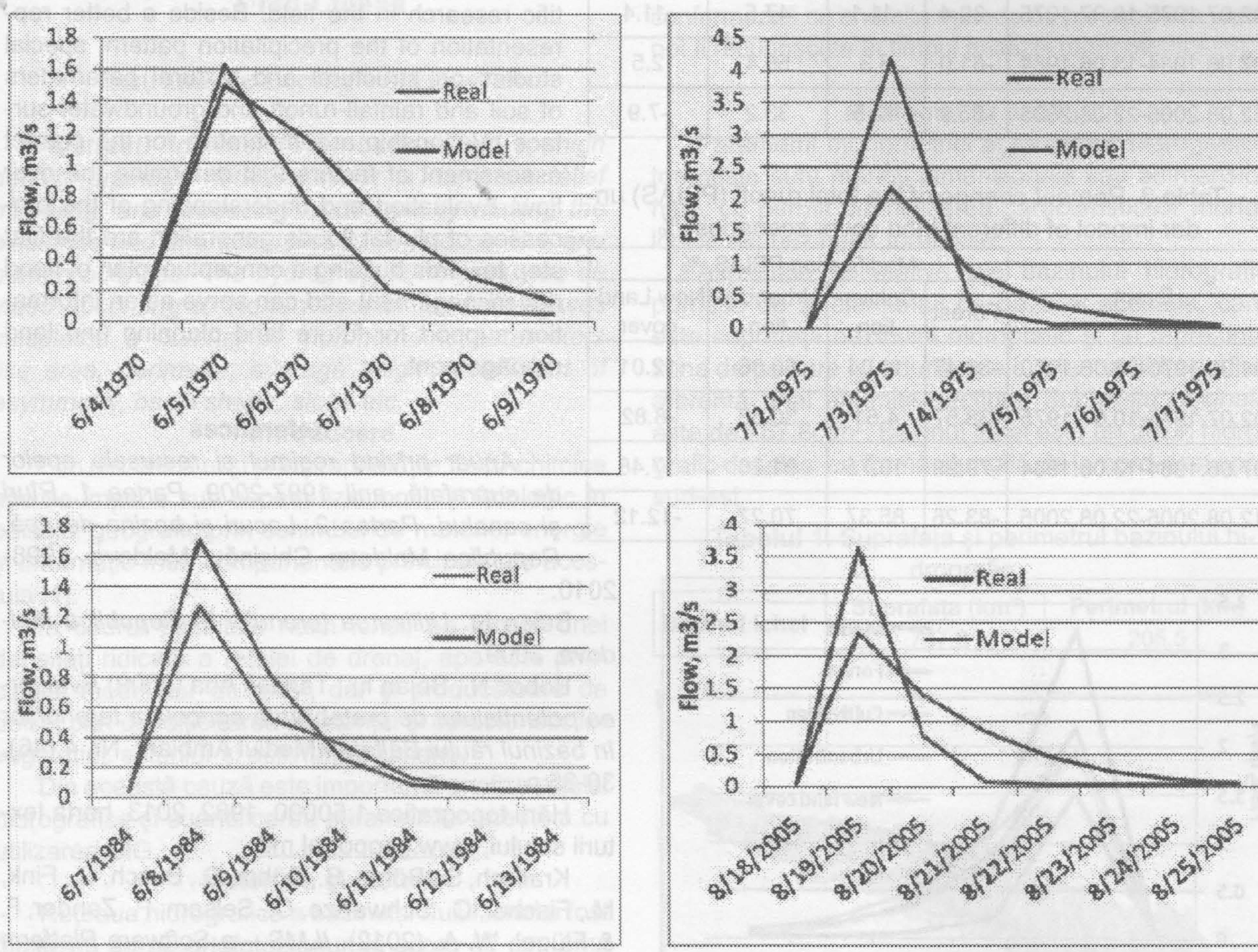


Figure 6. Measured and modeled flow

In Fig. 6 different major flood events are displayed, the results show a tendency for damping the measured signal in the model. Despite of this, the model sometimes over and sometimes underestimates the peak flow. One reason for this behavior can be that the rain patterns are not always cached correctly by the measurement network.

The next step consists of simulation of different land cover scenarios using the established hydrological model to understand the flood wave behavior under human impact. For this study 3 analytical extreme scenarios which show the theoretical possible variation of stream flow modifications caused by different land covers were used. One more realistic scenario of land cover modification is developed and applied. First scenario consist of covering the entire basin only with forest (the most optimistic scenario in terms of flood prevention). Second extreme scenario covers the basin with cultivated land. The most pessimistic scenario is considered when the basin is covered with urban area. Last model consisted in an attempt to create a new layer of land cover according to the slope [2] in combination with existing forest and settlements: 0-5° - cultivated land, 5-10° - grassland/shrubs, 10-15° - shrubs (including vineyards), 15°< forest. Modeled land cover map does not differ much from current map, a reduction can be seen only of cultivated land. The results shown in Tab. 2, 3 indicate that forest has a distinct reducing effect on both the total runoff and the flood peaks, whereas urbanization has the opposite effect. The new land cover shows no systematic difference to the existing land-cover except for the highest flow events 1975 and 2005 (Fig. 7) were a reduction of about 10% is achieved.

Conclusions

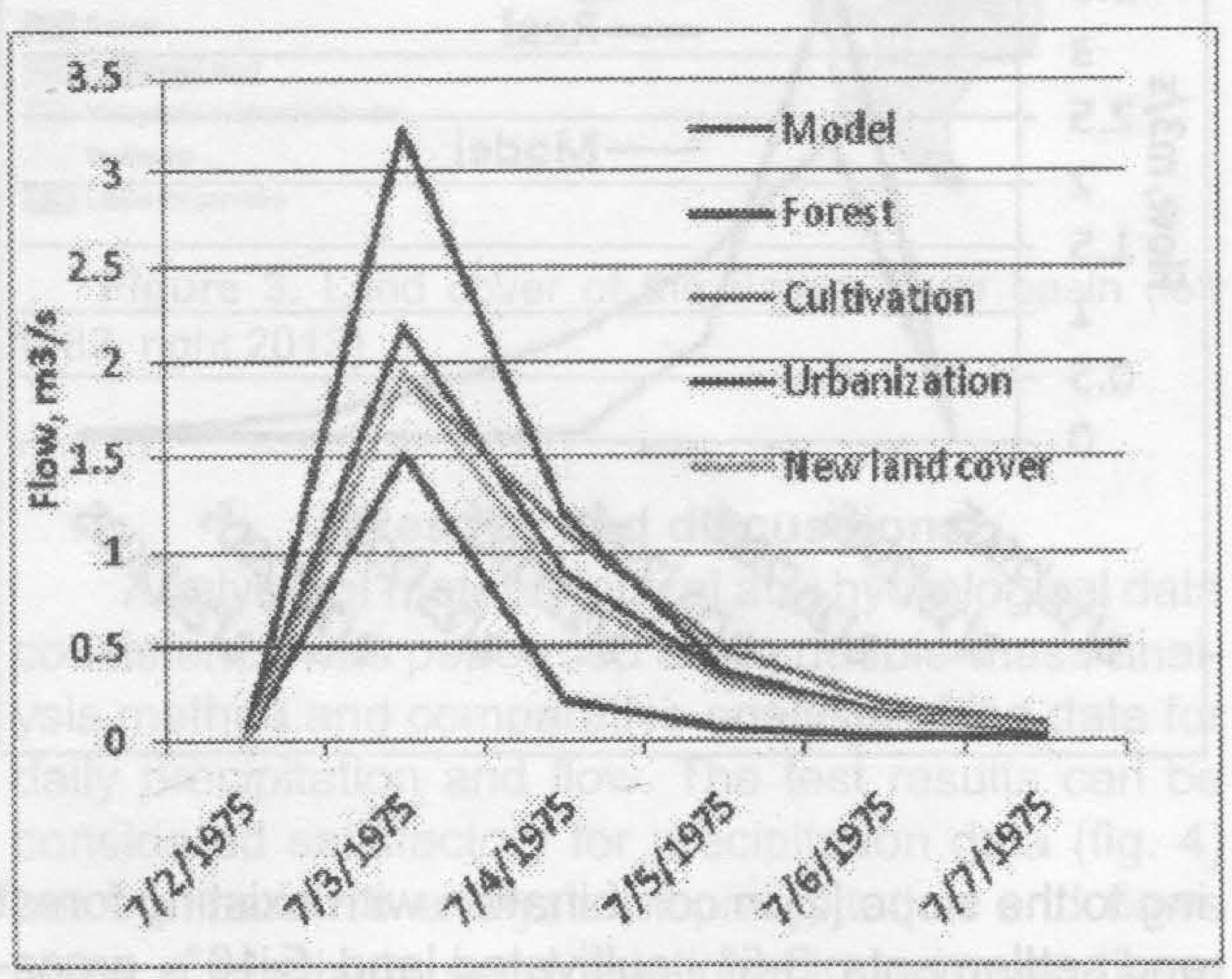
Present research represents the first attempt to apply hydrological modeling for simulation of flood dynamics on rivers of the Republic of Moldova. Despite the fact that physical-based, fully distributed models require a large number of temporal and spatial data and a better understanding of the processes occurring in the catchment, advantage of these

Table 3. Modification of daily maximal flow under impact of different land cover scenarios, %

Event	Modification daily maximal flow, %			
	Forest	Cultiva-tion	Urbaniza-tion	New Land-cover
04.06.1970-08.06.1970	-33.1	-4.9	32.2	-5.4
02.07.1975-10.07.1975	-30.4	-11.1	47.5	-11.4
07.06.1984-13.06.1984	-61.0	5.3	56.4	2.5
12.08.2005-22.08.2005	-55.9	42.5	33.2	-7.9

Table 3. Percent change of the total runoff (PBIAS) under impact of different land cover scenarios, %

Event	Modification PBIAS, %			
	Forest	Cultiva-tion	Urbaniza-tion	New Land-cover
04.06.1970-08.06.1970	-39.47	11.04	60.06	12.01
02.07.1975-10.07.1975	-38.57	4.61	30.66	-8.82
07.06.1984-13.06.1984	-79.29	10.75	91.20	17.48
12.08.2005-22.08.2005	-83.26	85.37	70.27	-12.12



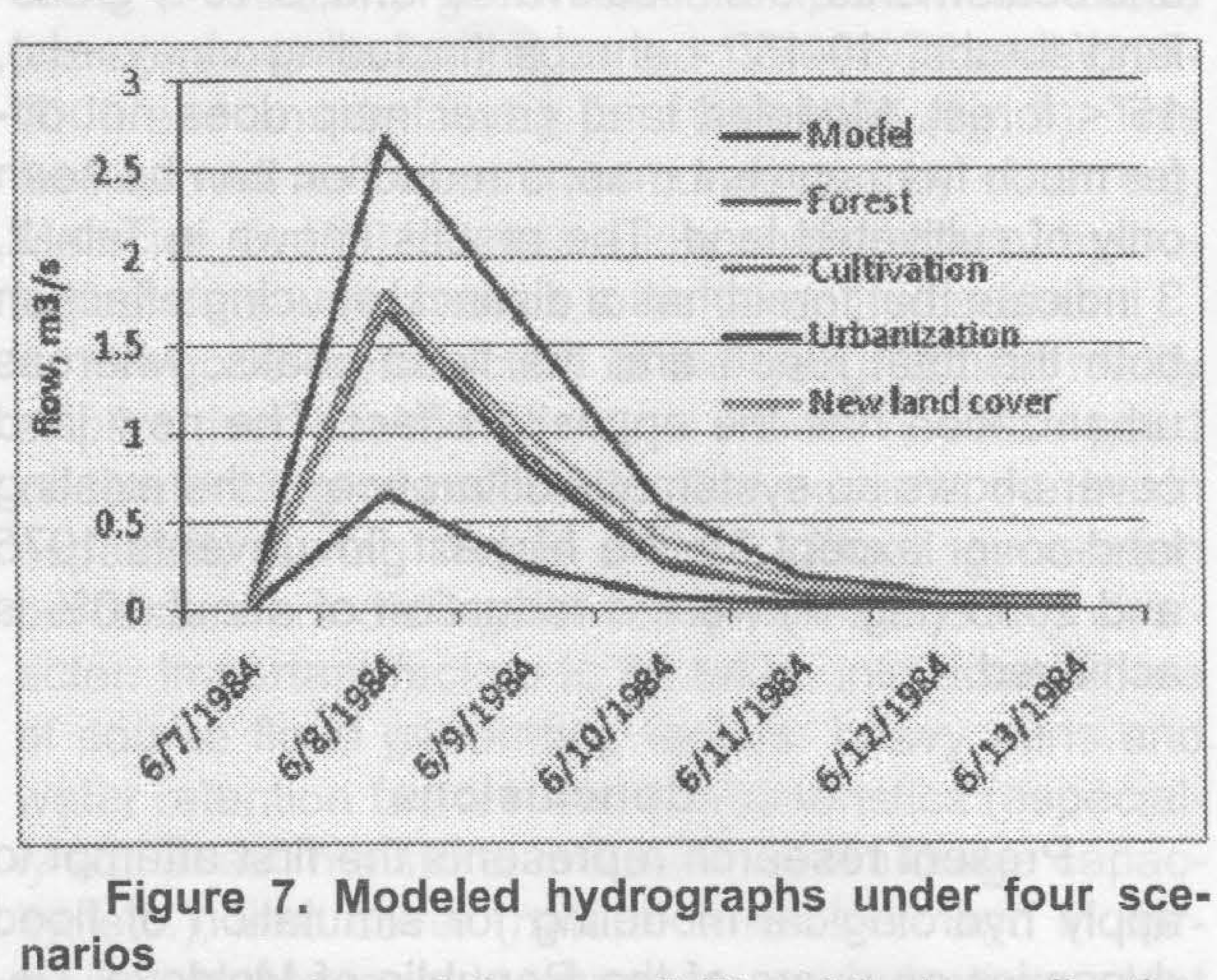


Figure 7. Modeled hydrographs under four scenarios

models consists of the possibility of their application in assessing human impact (such as land cover) on river flow. The presented hydrological modeling on example of the Baltata river shows the possibility to estimate the influence of land cover changes on runoff generation. In this case a strong increase of the peak flow can be observed by increased impervious surfaces of settlements, the other extreme is represented by forest. This results are in line with the common hydrological knowledge.

Improvement of the current hydrological model requires additional information and scientific research in the field. Beside a better representation of the precipitation pattern, special studies on structural and textural parameters of soil and rainfall-runoff and groundwater-surface relationship are imperative for the correct assessment of factors that determine the river flow. Evaluation and understanding of the processes of pluvial floods generation are the first step towards building a conceptual plan of flood risk management and can serve as an information support for future land planning and land management.

References

Anuar privind regimul şi resursele apelor de suprafaţă, anii 1997-2009. Partea 1. Rîuri şi canaluri. Partea 2. Lacuri şi bazine de apă. Republica Moldova. Chişinău, Moldova. 1998-2010.

Bejan Iu. *Utilizarea terenului în Republica Moldova,* 2009.

Boboc N., Bejan Iu., Tănase Ana (2009) *Evaluarea potenţialului de pretabilitate agricolă a terenurilor în bazinul râului Bălţata* //Mediul Ambiant. Nr. 4 (46), 30-35 p.

Hărţi topografice 1:50000, 1982, 2013, harta texturii solului, www.geoportal.md;

Kralisch, S., Böhm, B., Böhm, C., Busch, C., Fink, M., Fischer, C., Schwartze, C., Selsam, P., Zander, F. & Flügel, W.-A. (2012). *ILMS – a Software Platform for Integrated Water Resources Management.* Proc. Int. Congr. Environ. Model. Softw. Sixth Bienn. Meet. (R. Seppelt, A. A. Voinov, S. Lange & D. Bankamp, eds.). Leipzig, Germany;

Krause, P. & Kralisch, S. (2005). *The hydrological modelling system J2000 - knowledge core for JAMS.* Proc. Modsim 2005 Int. Congr. Model. Simul. (A. Zerger & R. M. Argent, eds.), 676–682. Melbourne, Australia.

Landsat, imagini satelitare pentru Republica Moldova, anii 1975, 1989, 2004, 2010, http://glovis.usgs.gov/

Moriasi DN, Arnold JG, Van Liew MW, Bingner RL, Harmel RD, Veith TL (2007) *Model evaluation guidelines for systematic quantification of accuracy in watershed simulations.* Am. Soc Agric. Bio. Eng 50(3):885–900

Материалы наблюдений Молдавской воднобалансовой станции, 1970-1978, 1983-1994, Киев, 1972-1995.;

Мельничук О. *Паводки и наводнения на реках Молдовы.* Кишинэу, 2012, 233 с.